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THE ACTION OF ELECTRICALLY CHARGED COPPER UPON CERTAIN ORGANISMS IN WATER.

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THAT metallic copper, when placed in water containing algæ or certain bacteria, will kill these organisms seems to be beyond doubt. That the area of copper surface exposed must be quite extensive and that the period of contact is of considerable duration is shown, also, in the experiments already published by a number of investigators. The formation of colloidal copper is, under natural conditions, slow, hence the tardiness in germicidal activity. Could this production of colloidal metal be hastened it is quite possible that a marked reduction in the lethal time would ensue. For the preparation of such solutions the electric current has been found most satisfactory, hence a trial has been made of the action of charged copper plates on certain pathogenic organisms suspended in river water.

As a preliminary experiment, copper foil was placed in a measured quantity of water for twenty-four hours, after which it was removed and weighed. The loss in weight for the same sample of foil was quite constant, being about 0.0006 gram for six square inches of copper surface in twenty-four hours. These copper strips when serving as anode and cathode, with a current of 4 volts and less than 0.01 ampere, lost copper at the rate of 0.0039 gram in one hour. This determination was made a number of times with closely agreeing results.

Other samples of copper-foil gave, under similar conditions, results agreeing among themselves but differing from those already cited. One sample of copper was, therefore, used throughout this work.

Having determined the rate of removal of the copper from the electrodes, they were placed in water containing B. typhosus. In another experiment B. coli was used. The water was from the laboratory tap, and was sterilized in an autoclave. Seeding was from an aqueous suspension of the organisms grown on agar slants for eighteen to twenty-four hours at incubator temperature. Control experiments made with water and organisms alone showed practically no change at the end of the experiment period. To determine the action of the current without the copper, platinum strips were substituted, with the result shown in Table 1, *C*.

TABLE I.—Electrode surface 6 square inches. Current 4 volts, and less than 0.01 ampere. Volume 1000 c.c., 1 c.c. plated.

A.

	Before treating.	15 minutes, copper 1 to a million.	30 minutes, copper 2 to a million.	45 minutes, copper 3 to a million.
B. typhosus . . .	40,000	125	60	1
	44,000	230	20	1
	107,520	80,500	60	1
	100,400	76,420	36	0

B.

	Before treating.	15 minutes, copper 1 to a million.	30 minutes, copper 2 to a million.	45 minutes, copper 3 to a million.
B. coli communis . .	Innumerable.	Innumerable.	89,000	55,600
			80,000	54,500

C.

	Before treating.	15 minutes, platinum electrodes.	30 minutes, platinum electrodes.	45 minutes, platinum electrodes.
B. typhosus . . .	34,000	24,800	16,200	8,640
	30,000	21,600	18,900	

Is it possible to pass water at the intake of a reservoir over charged copper plates at such a rate that pathogenic organisms, particularly B. typhosus, are destroyed in transit? If not killed in transit, would the copper taken up by the water be sufficient to kill them within a reasonable time?

The following very primitive device was used to simulate a reservoir with intake and outlet.

A glass jar of four litres' capacity was fitted with two perforated copper disks, forming the positive and negative poles and exposing about 31 square inches of surface. A wooden cover, carrying inlet and outlet tubes as well as the wires for the electric supply, fitted the top of the jar accurately. Its joint was packed with cottonwool as were also the openings for wires and tubes. The entire piece of apparatus, except the copper disks, was sterilized in an autoclave. The copper was sterilized by igniting several times in alcohol, thereby preserving its brightness. A supply jar at a higher level carried an infected stream of water to the bottom of the reservoir whence it flowed up, over and through the perforated disks, and out by a siphon tube, dipping just below the surface of the liquid. Screw clips regulated the rate of flow, and every care was taken to guard against contamination. The amount of copper lost was found by weighing the disks, and was 0.00032 gram per minute. After five minutes' action, then, a litre of water contained 1.6 part copper per million. Plates were made immediately upon the exit of the effluent, and again after it had stood at room temperature for one hour. Controls in water, alone, showed practically no change at the end of thirty minutes nor after one hour.

TABLE II.

	Before treating.	1 minute.	2 minutes.	5 minutes.
B. typhosus	102,600	1360	1380	729
	98,600	1870	1300	900
	180,000	1700	......	1000
	170,000	1800	......	1080

	Before treating.	1 min.	2 min.	5 min.	10 min.
B. coli communis	42,120	3300	2400	980	485
	42,660	4116	2520	1060	600
	43,200	......	2100	1392	864
	45,900	......	2320	1104	605

After standing for one hour plating the effluent showed the number of organisms per cubic centimetre to be as follows:

Time.	B. typhosus.	B. coli communis.
1 minute	36	22
2 minutes	7	2
5 "	0	0
10 "	0	0

A comparison of the foregoing experiments would seem to indicate a balance in favor of a large copper surface with which the organisms come in contact, rather than the actual copper content of the water. Accordingly, another apparatus was arranged in which the water passed over four plates, placed about an inch and a half apart in a glass tube holding 200 c.c.

The copper disks, perforated as before, gave a surface of 9.6 square inches. As the disks were four in number the organisms in their descent were compelled to pass over the four separate surfaces, an interval elapsing between leaving one and reaching the next. Electrolyzed in tap-water, they showed a loss of 0.00014 gram copper per minute for 4 volts and 0.02 ampere. Portions of

500 c.c. were used, giving the water a copper content of 1.4 parts per million for five minutes and 2.8 parts for ten minutes.

TABLE III.

	Before treating.	5 minute.	10 minutes.
B. typhosus	,440	sterile.	sterile.
	50,200	"	"
	22,140	1	"
	28,900	3	"

In the making of these experiments the water in which the copper had been electrolyzed was subjected to the ferrocyanide test, and it was noted that when the organisms were not added to the water the reaction was much more distinct than that given by the same quantity of copper in the presence of the bacteria. In the latter case it was sometimes impossible to obtain any reaction with ferrocyanide.

SUMMARY. 1. Copper electrodes carrying a small current are actively germicidal for B. typhosus and B. coli communis.

2. B. typhosus is the more easily affected.

3. That it is the copper which plays the important role is shown by substituting for it platinum electrodes.

I am greatly indebted to Prof. Edgar F. Smith, of the John Harrison Laboratory of Chemistry, University of Pennsylvania, for placing at my disposal the facilities of the electrochemical laboratory, wherein the electric part of this work was carried out.

STUDIES ON THE BACTERICIDAL ACTION OF COPPER ON ORGANISMS IN WATER.

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THE investigations of Moore and Kellerman[1] on the employment of copper for the destruction of algæ, and incidentally of bacteria, in water, have developed an excellent method for the destruction of certain algæ which have caused a great deal of annoyance, the presence of these cryptogams in water frequently causing a disagreeable odor and taste rendering it unfit for household, and, in many instances, industrial purposes. Such waters while they are not, in the present state of our knowledge on the subject, looked upon as being especially detrimental to the health of a community, will be condemned, and justly, on account of their disagreeable

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[1] Bulletin, No. 64, Bureau of Plant Industry.